The StarLight mission: a formation-flying stellar interferometer

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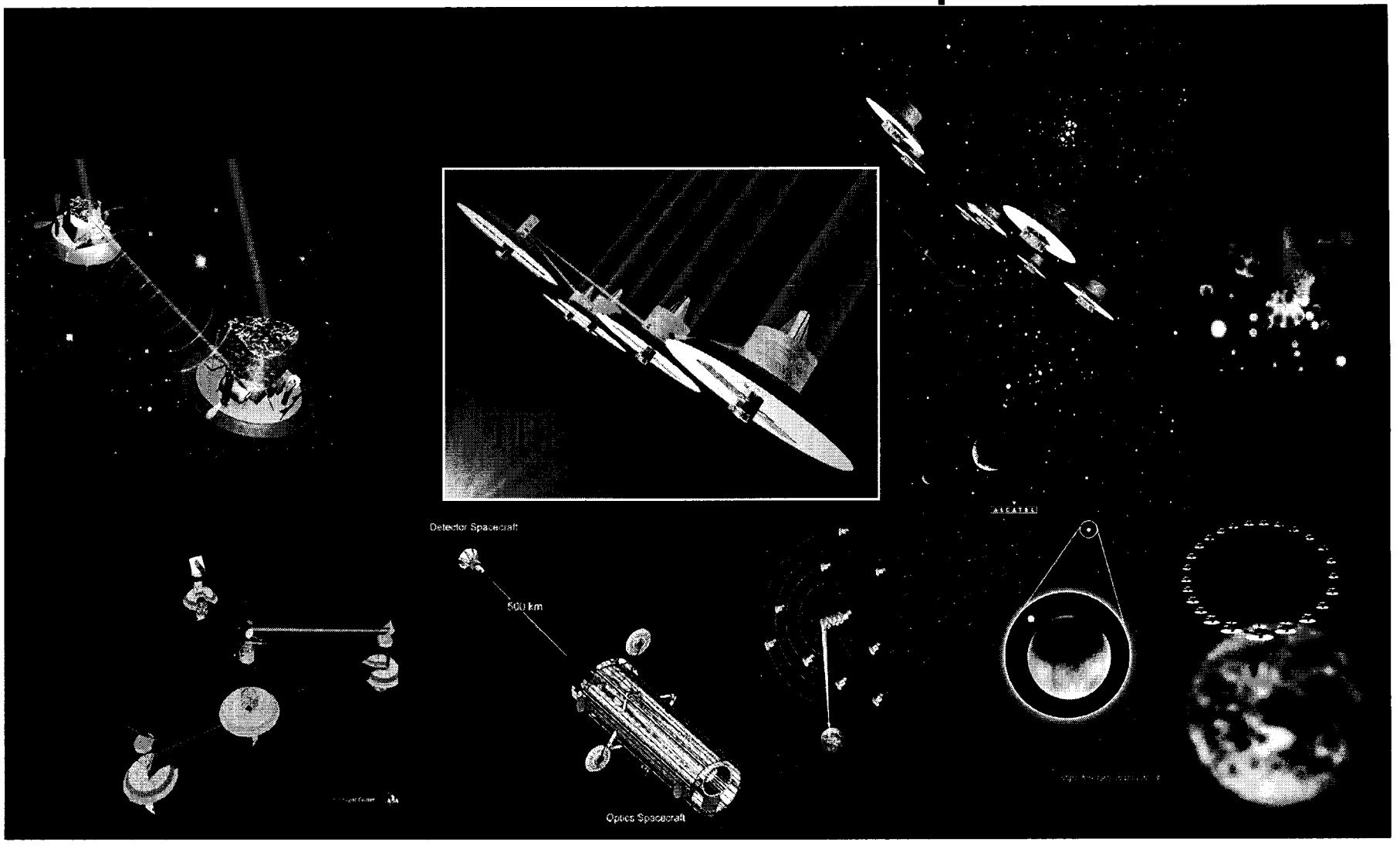
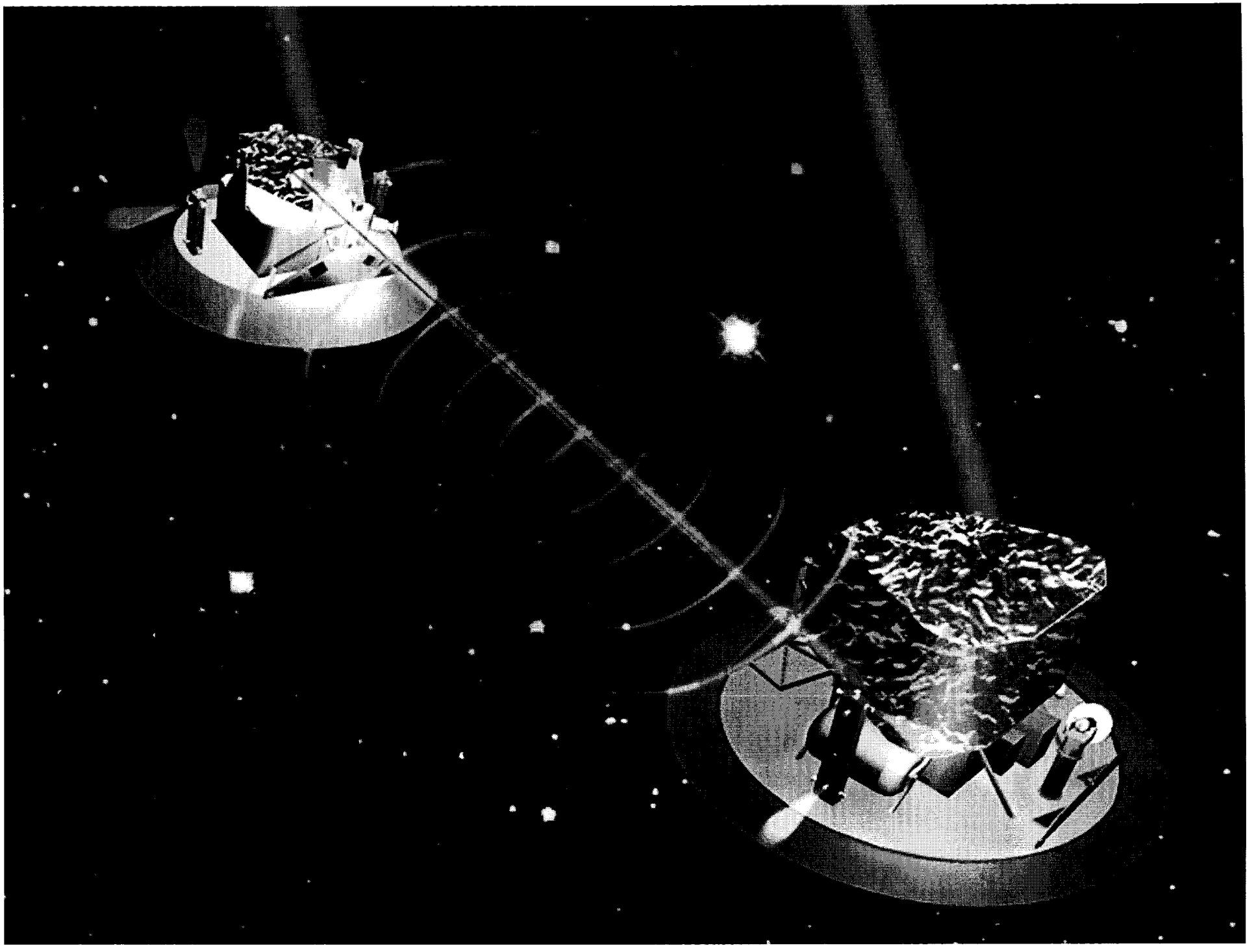
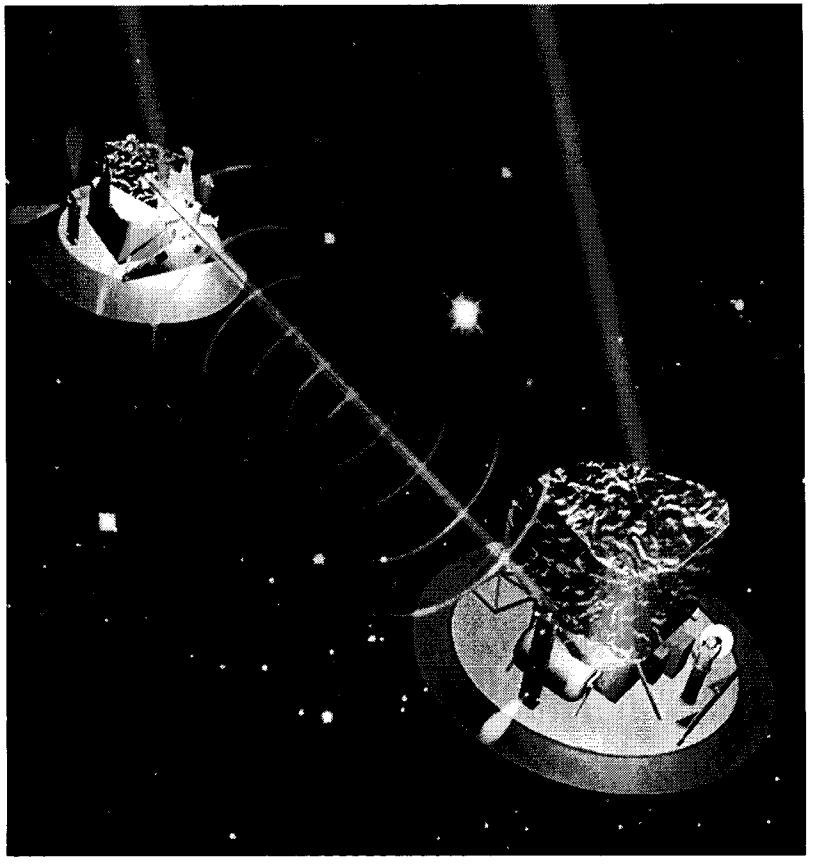
Formation Telescopes





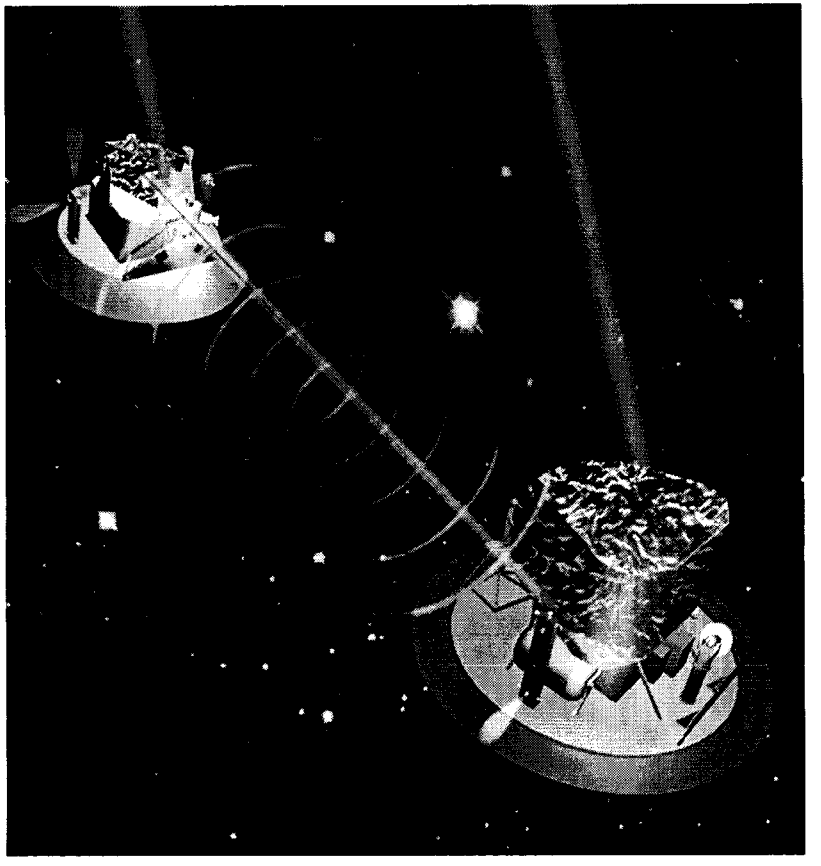
Mission Description

- Formation-flight over ranges of 40 to 600m
- Interferometer projected baselines of 30 to 125m (including 1.3m standalone)
- Actuators: cold gas thrusters and reaction wheels
- Formation sensors: Ka-band AFF for range and bearing
- 1.3 um laser metrology



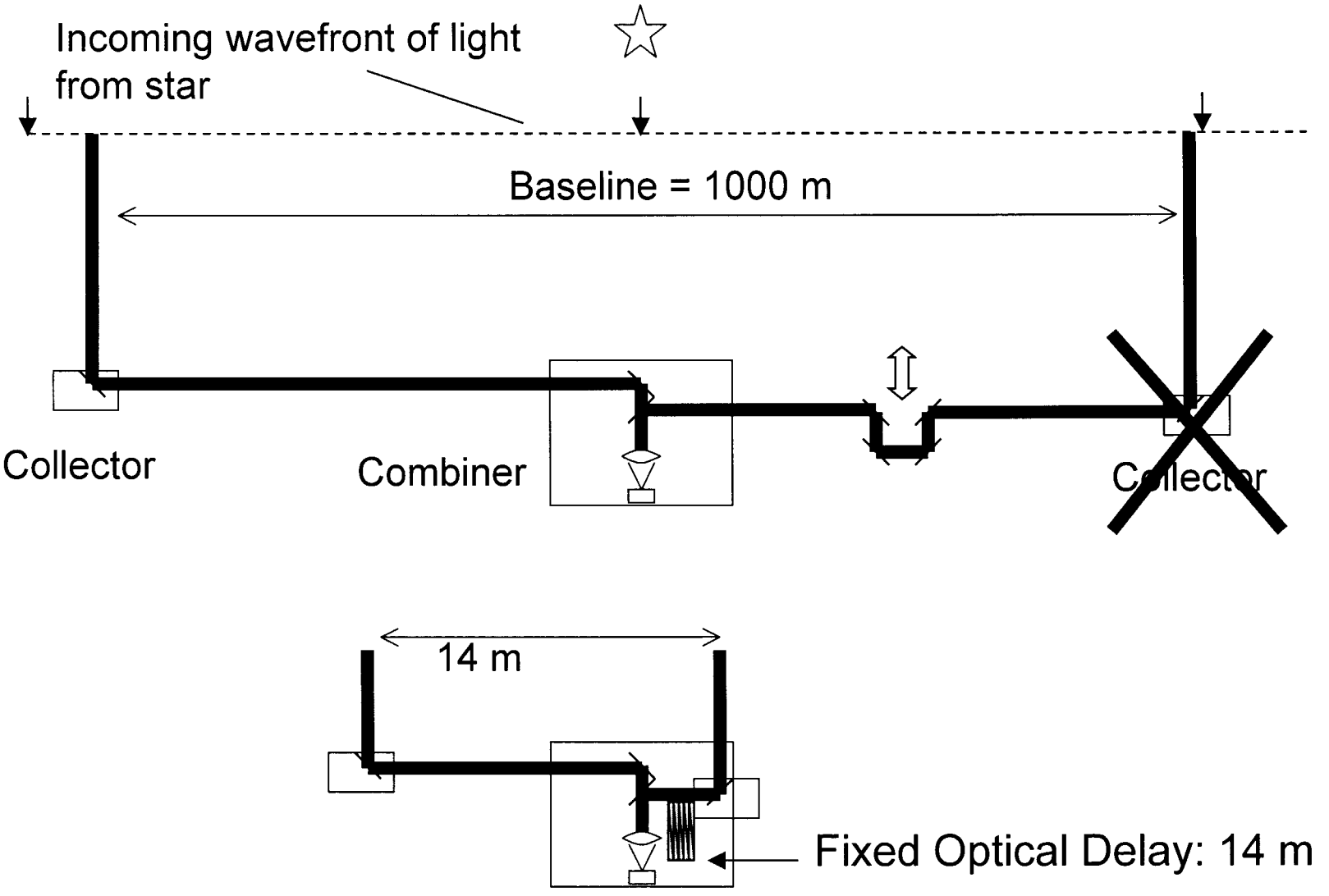
Instrument Description

- Michelson beam combiner
- Wavelength: 600-1000 nm
- 12 cm optics
- Sensitivity: Mv=5
- White-light fringe tracking, visibility amplitude measurement on ~20 stars
- Baseline rotations of +/- 25 degrees on targets normal to sun vector
- 15 cm optical delay line

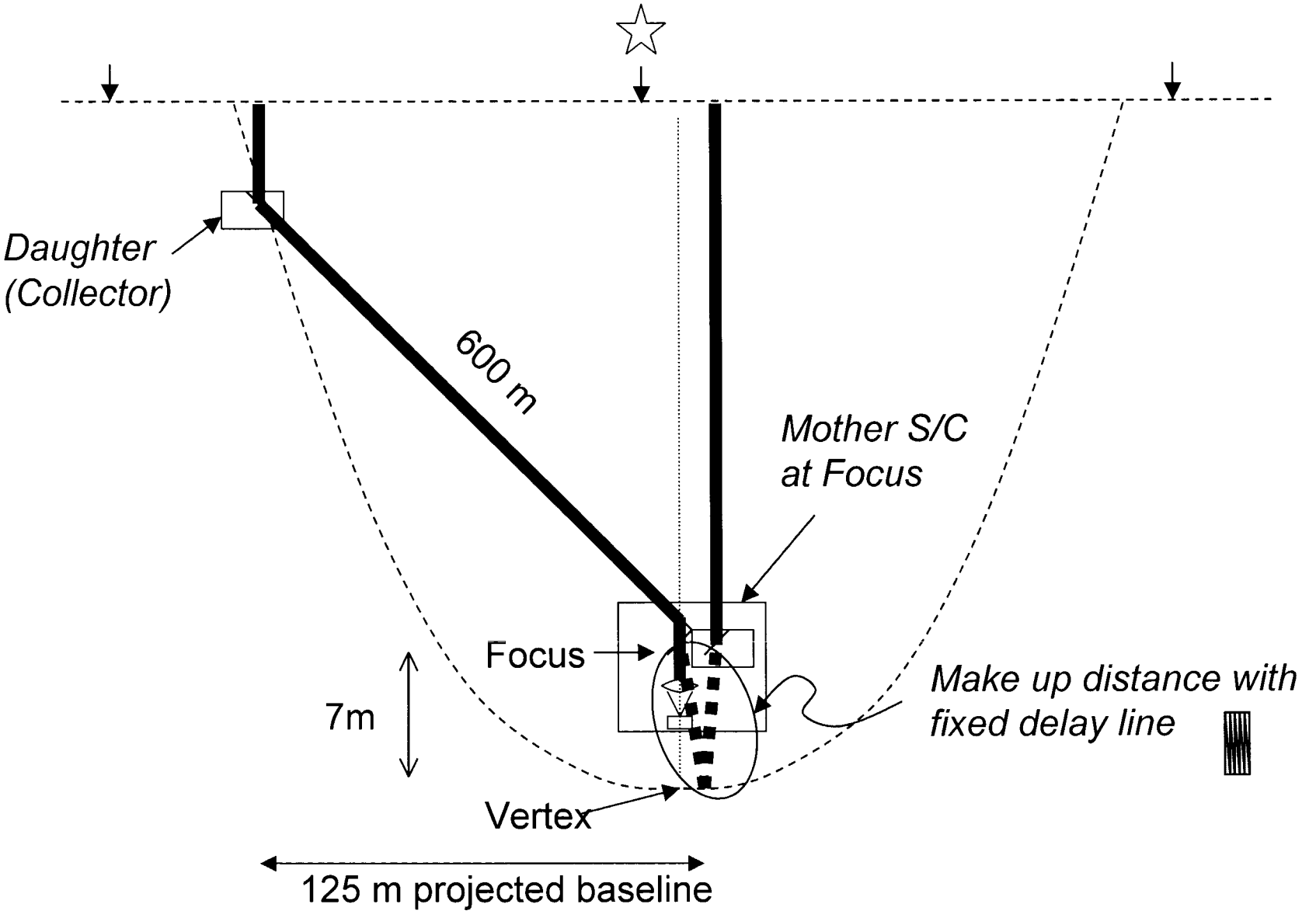


Aren't we missing one collector?

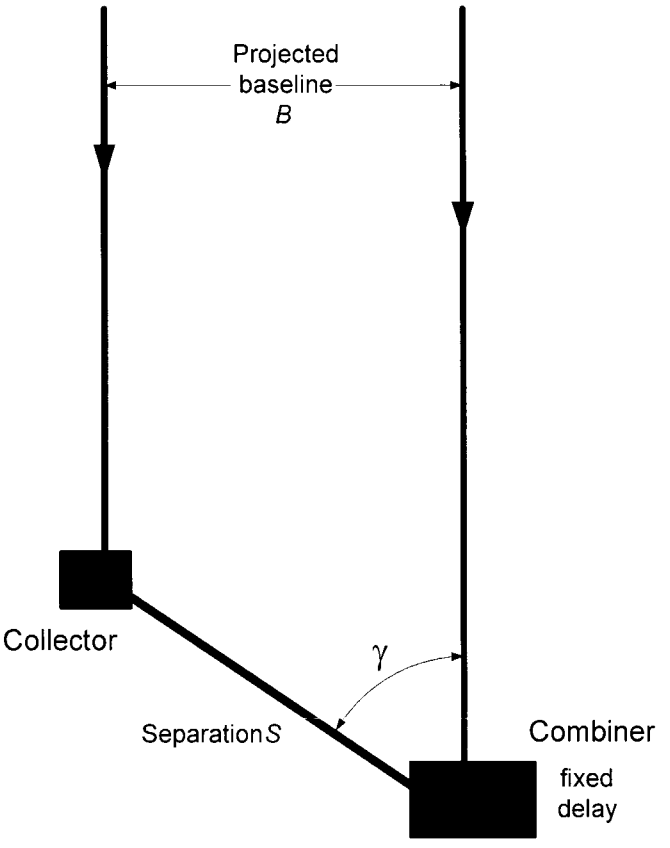
Original 3-spacecraft architecture

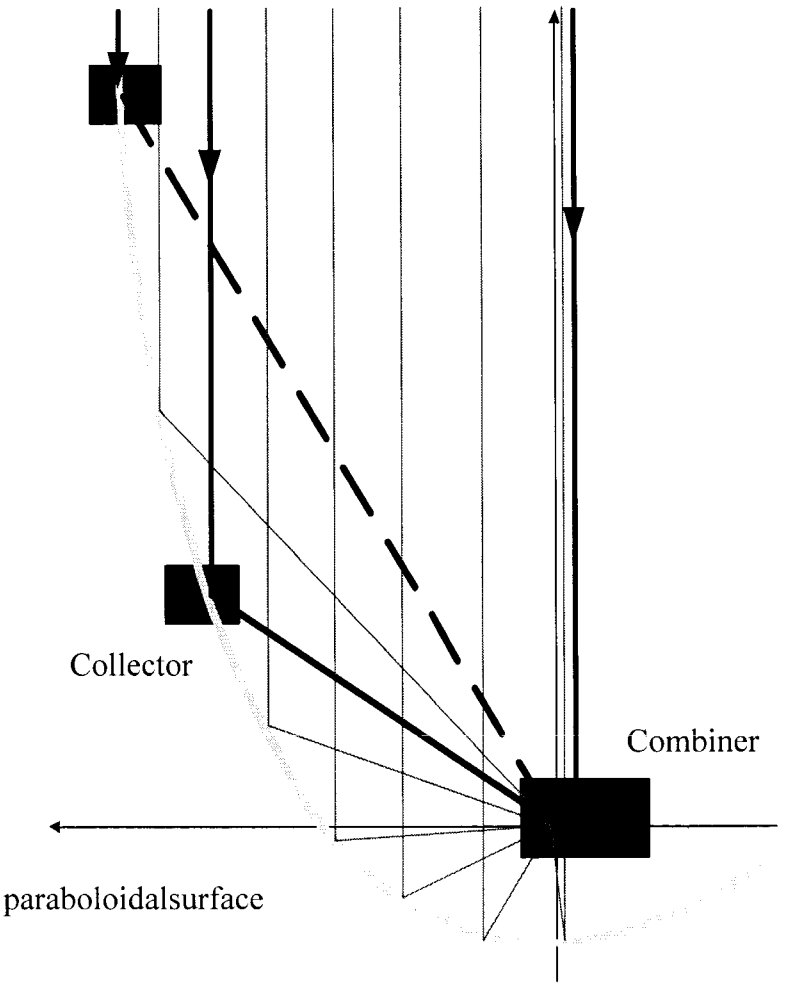


The Breakthrough: a Virtual Parabola



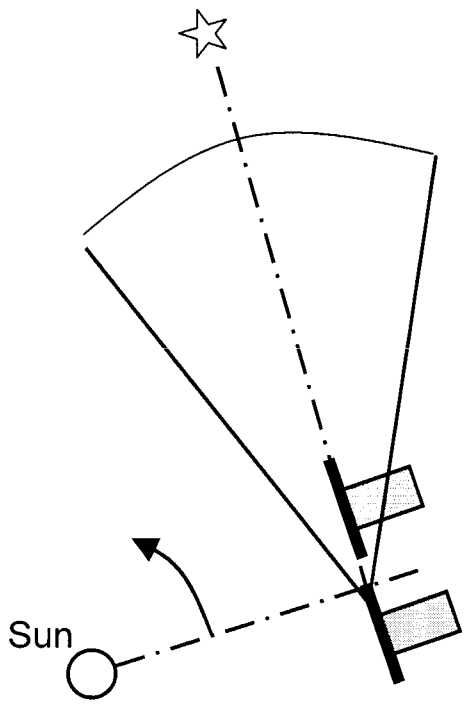
Baseline Coverage using two Spacecraft





Sky Coverage

- At one epoch: +/- 25 degrees normal to sun vector
  - Traces +/- 25 band on great circle
- Full sky coverage over 6 months
- Continuous coverage within 25 deg of the ecliptic poles

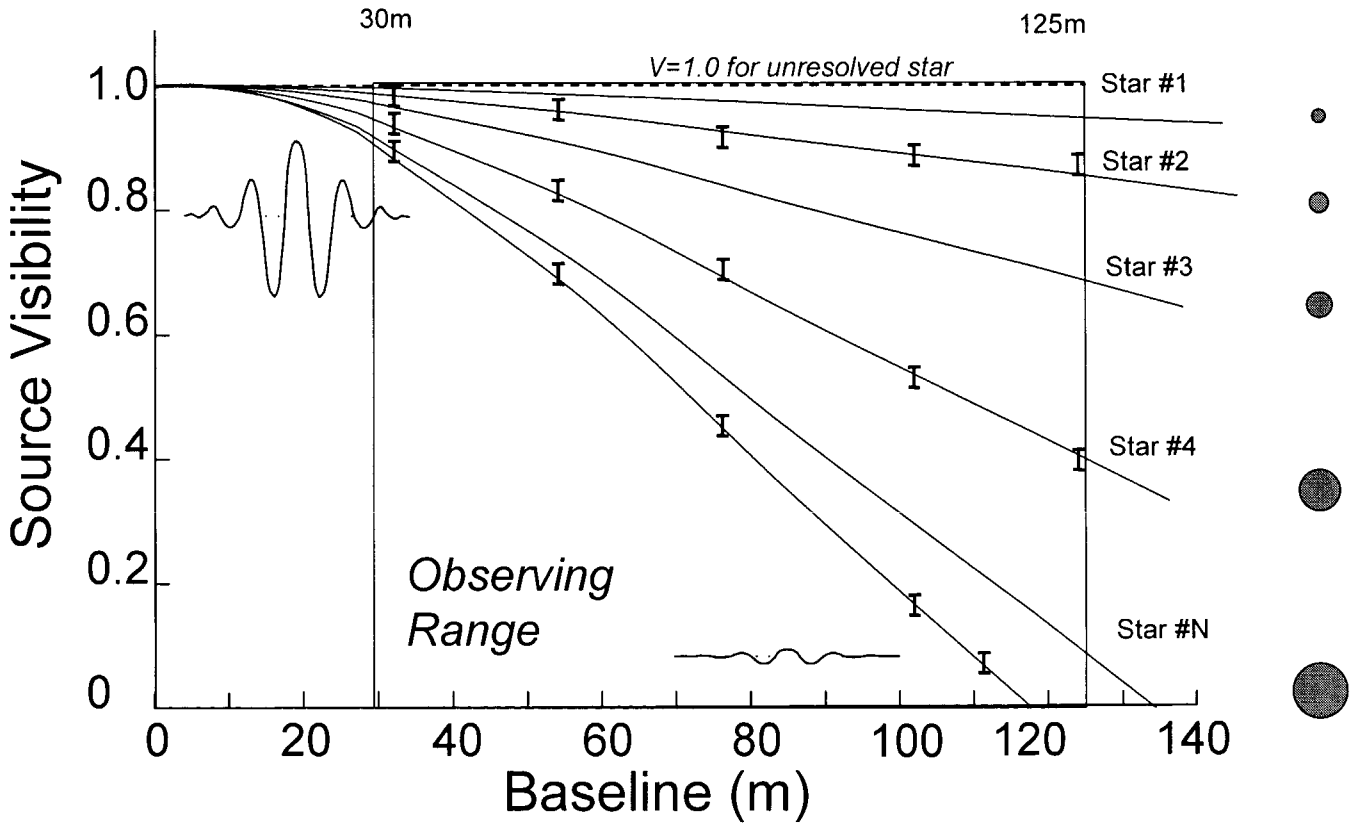


Looking in plane of parabola

Constellation is in earth-trailing Heliocentric orbit

Performance Validation: visibility measurements on ~20 stars

- Measure fringe visibility on a number of stars, at different baselines, and over time



Formation-Flying Performance:

- Formation Flying

	Control	Knowledge (rms)
– Range:	+/- 10 cm	2 cm
– Range rate:	+/- 1 mm/s	200 um/s
– Relative bearing:	+/- 4 arcmin	1 arcmin

➔ Permits optical acquisition between spacecraft

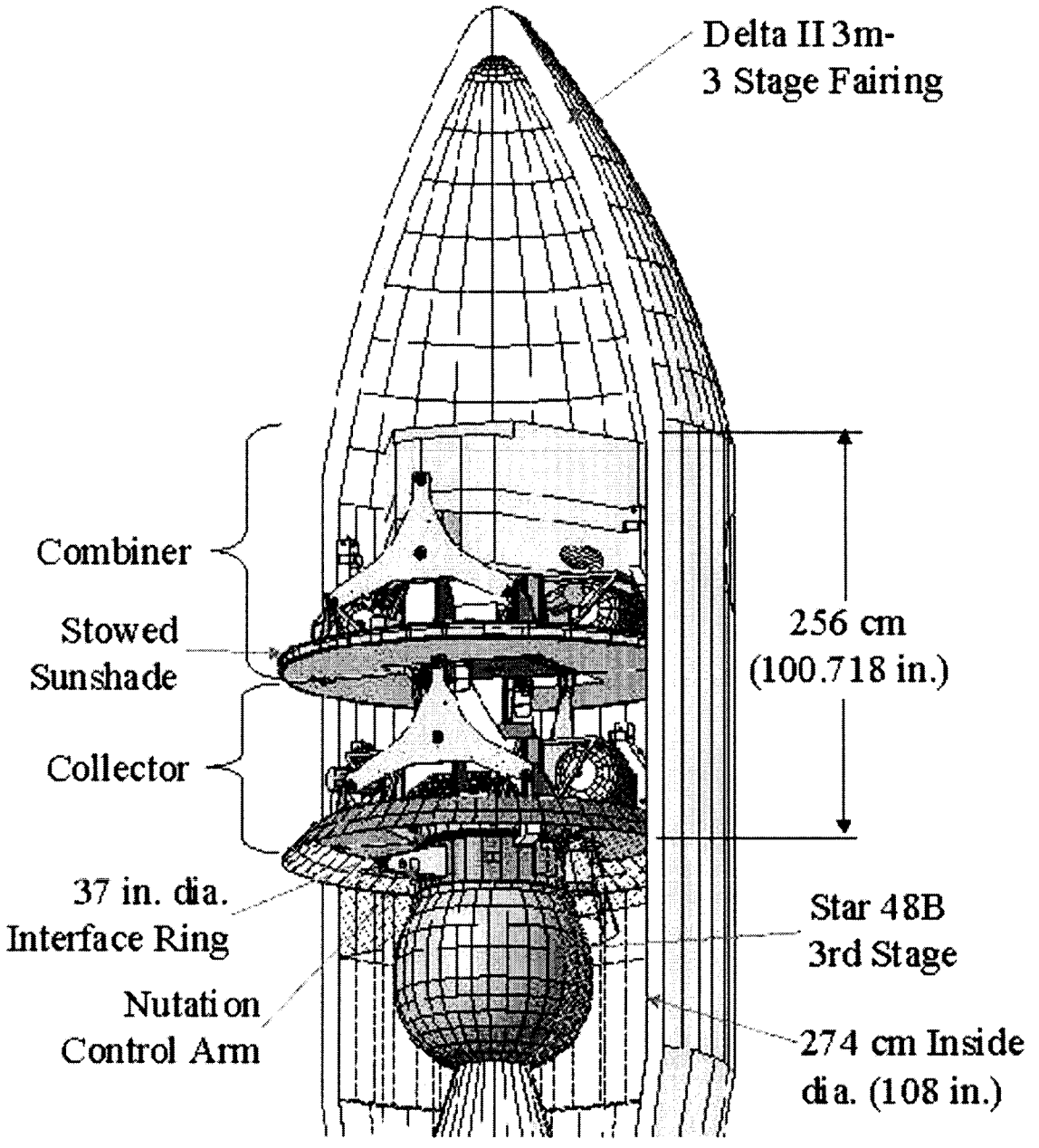
- Precision Formation Knowledge

– Range rate:	20 um sec
– Bearing knowledge:	20 asec
– Bearing rate knowledge:	20 masec/s

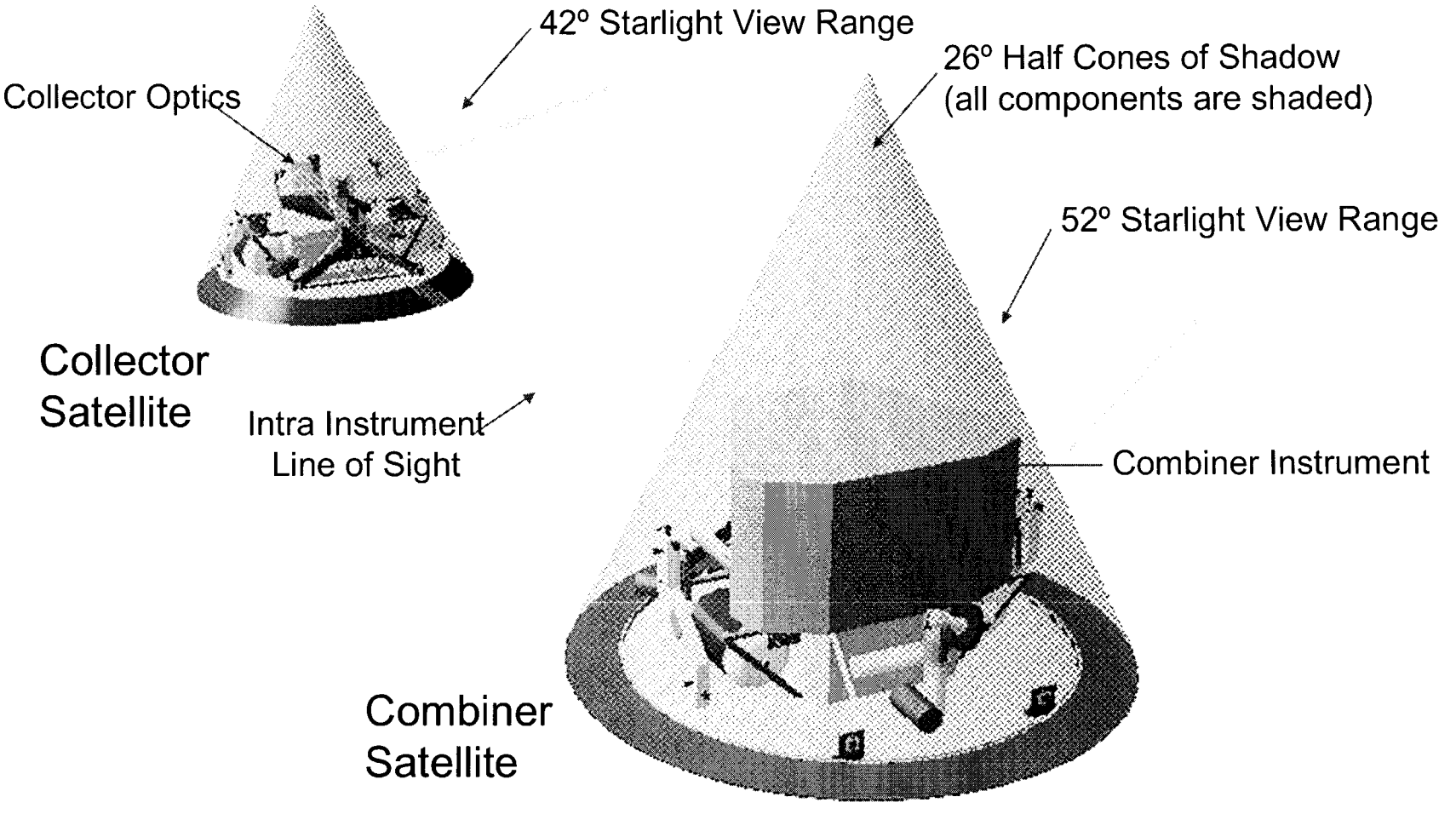
➔ Permits initiation of fringe search:

- 10 mm delay, 20 um/sec delay rate uncertainty (1 sigma)

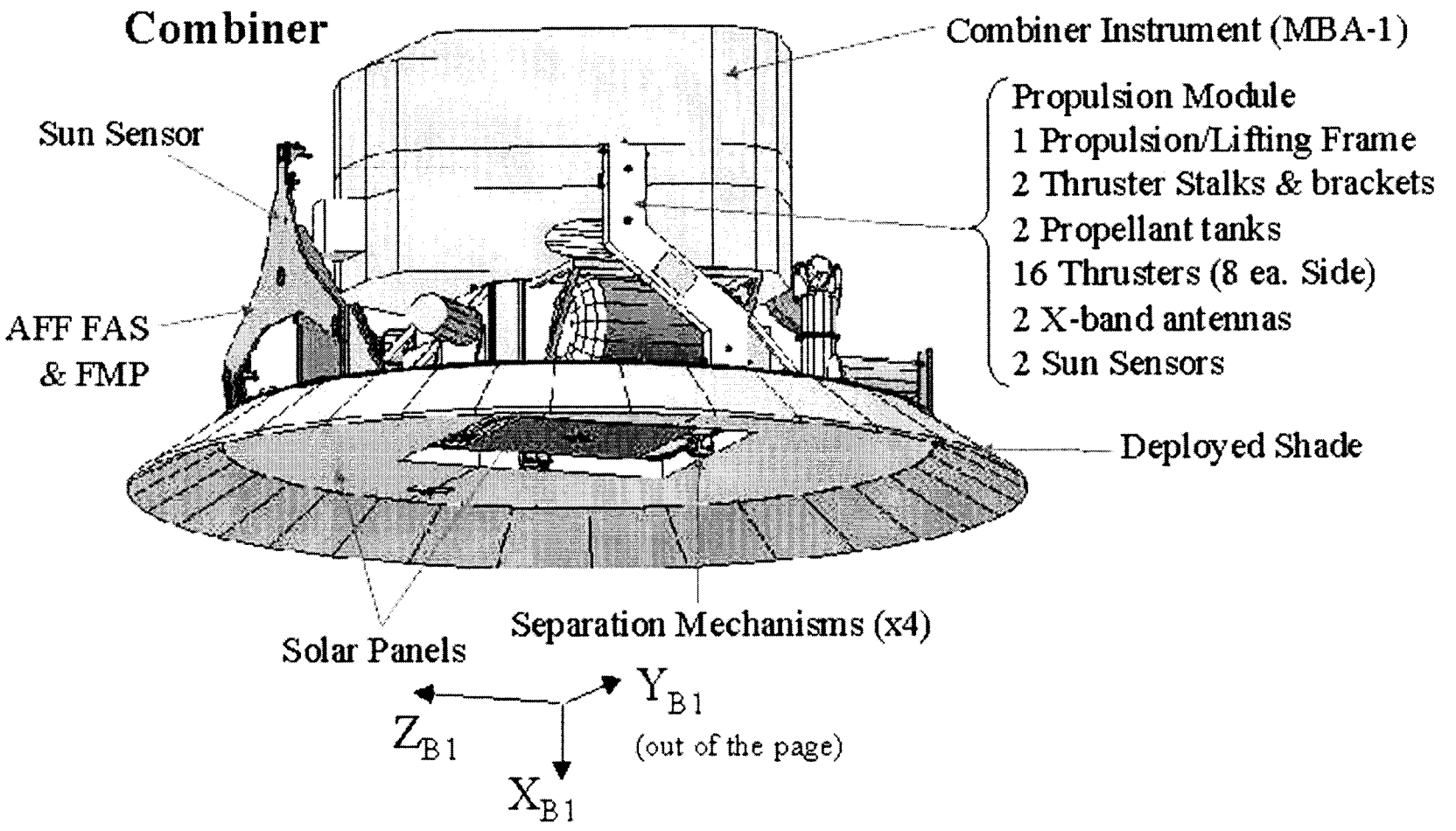
Spacecraft in Launch Faring



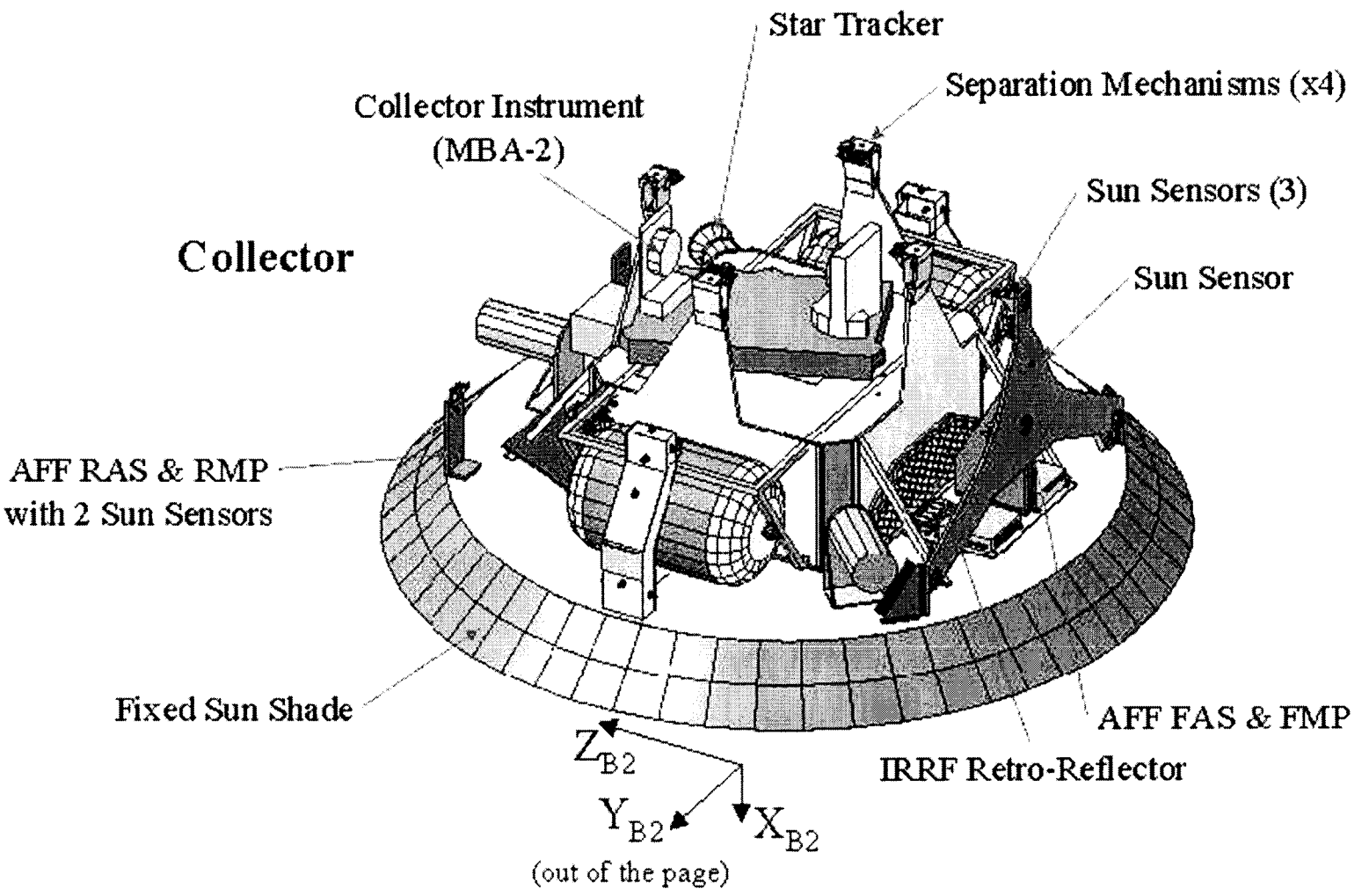
Mission Configuration



Combiner Spacecraft

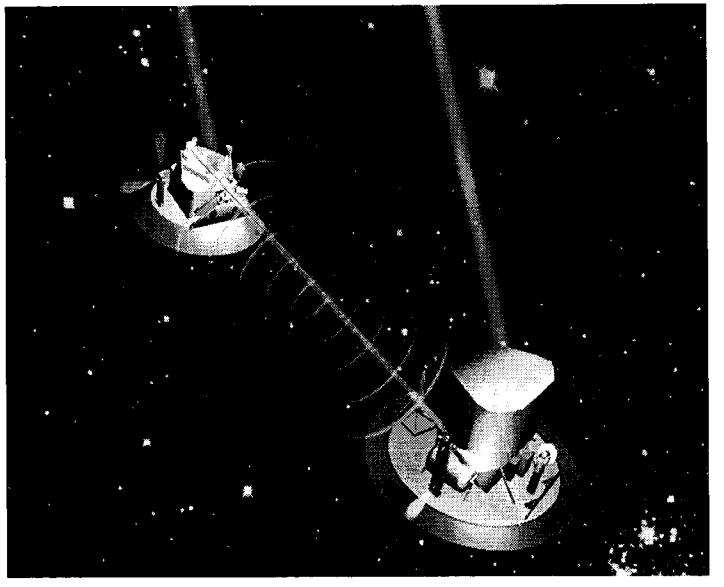


Collector Spacecraft

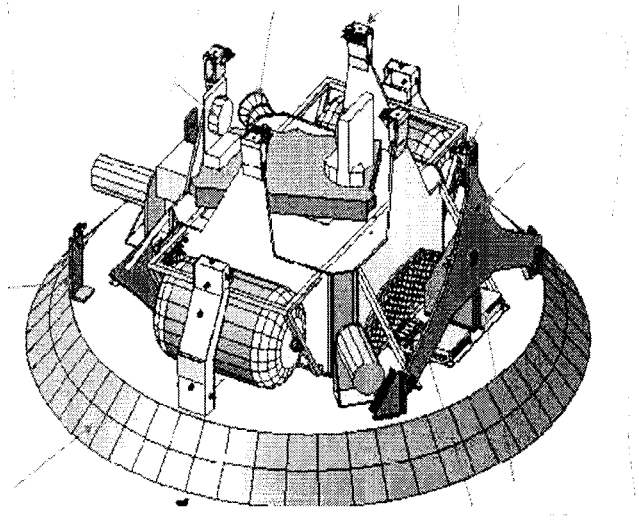


Autonomous Formation-Flyer (AFF) Sensor

- Ka-band radio-frequency (RF)
  - 2 cm range, 1 arcmin bearing
  - separations up to 1km
- No aid from Earth-based GPS system
- Near 4pi steradian field-of-view
- Signal processing algorithms based on GPS design
- No real-time ground-based interaction

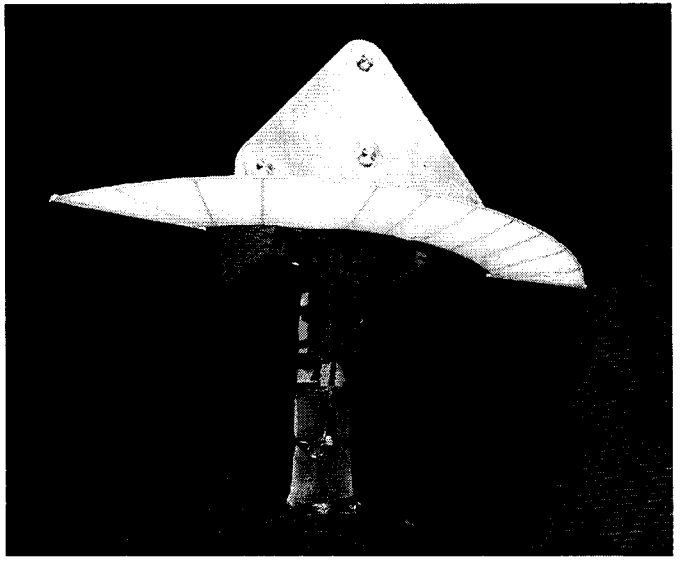


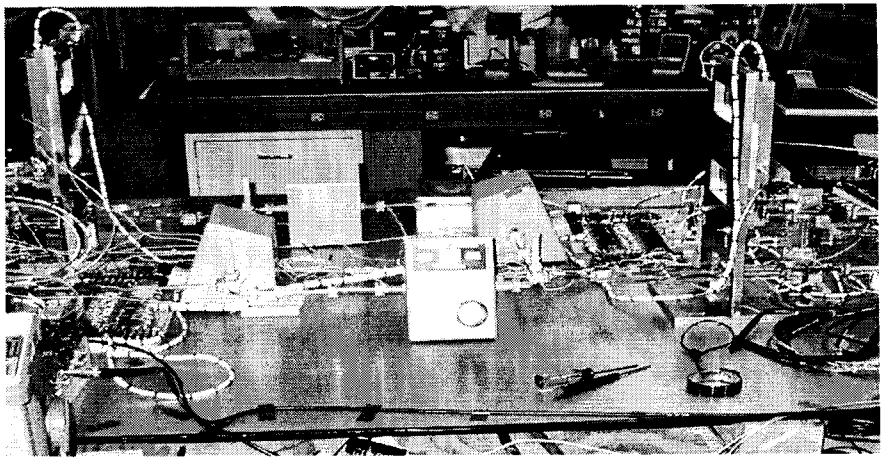
AFF Technical Challenges

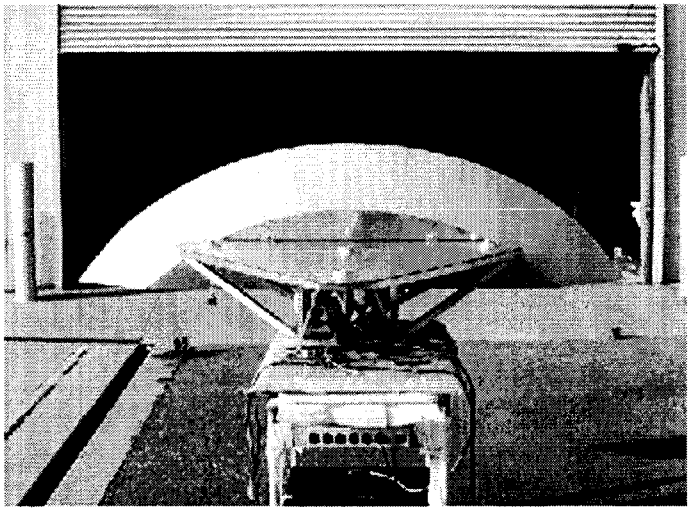


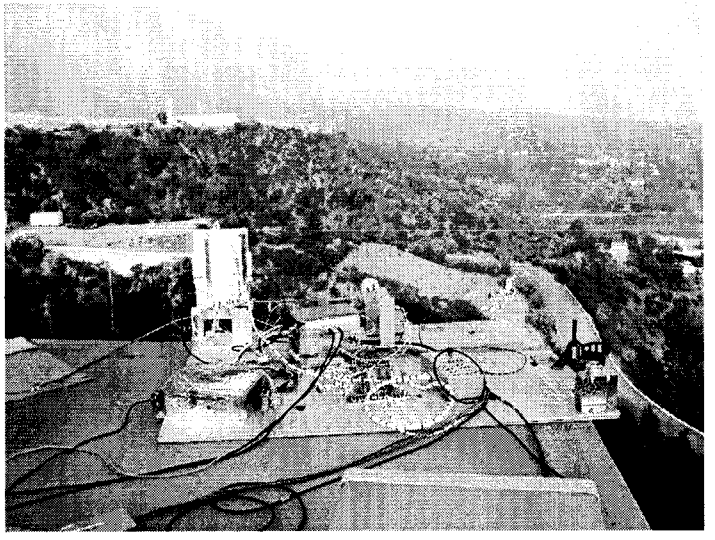
- A wide field of view (FOV), ±70° cone coverage with simultaneous high precision in preferred orientation
- Ka-band antenna performance within spacecraft structural environment
  - Multipath and diffraction effects – self-jamming, antenna patterns degradation
  - Sunshade (straylight concerns vs. multipath source)
- Continuous self-calibration
- Carrier-aided smoothing algorithm

AFF Technology Activities

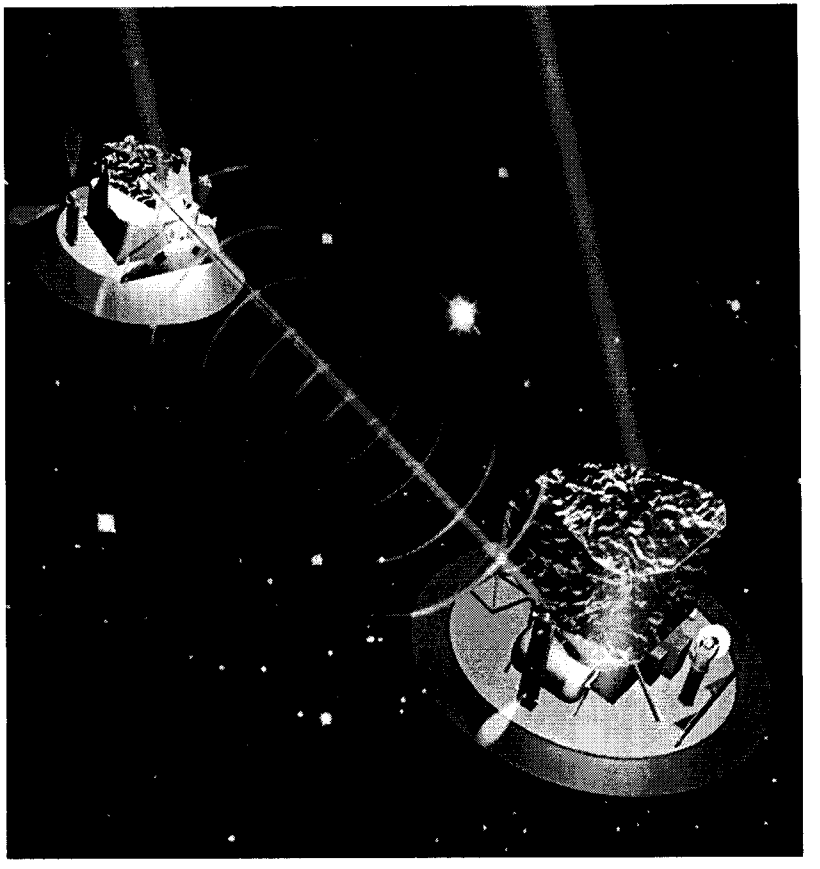






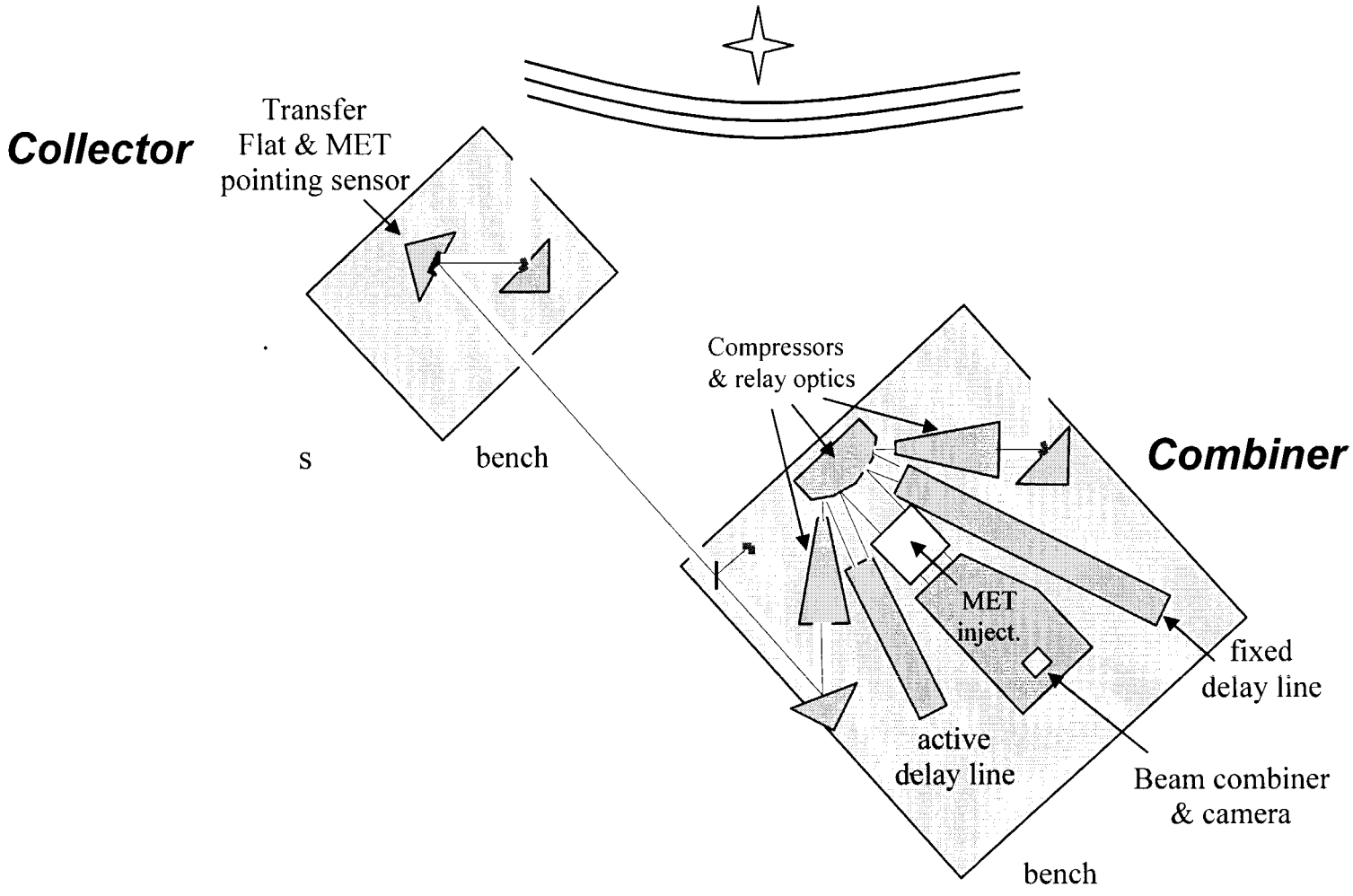


Description of Formation Flying



- Architecture
  - Master / slave
- Functions
  - Lost in space reacquisition
  - Constraint avoidance
    - Collision avoidance
    - AFF sensor constraints
    - Interspacecraft glint
    - Plume
  - Onboard autonomy
  - Successive calibrations
  - Minimization of onboard disturbances

Interferometer Instrument- functional diagram



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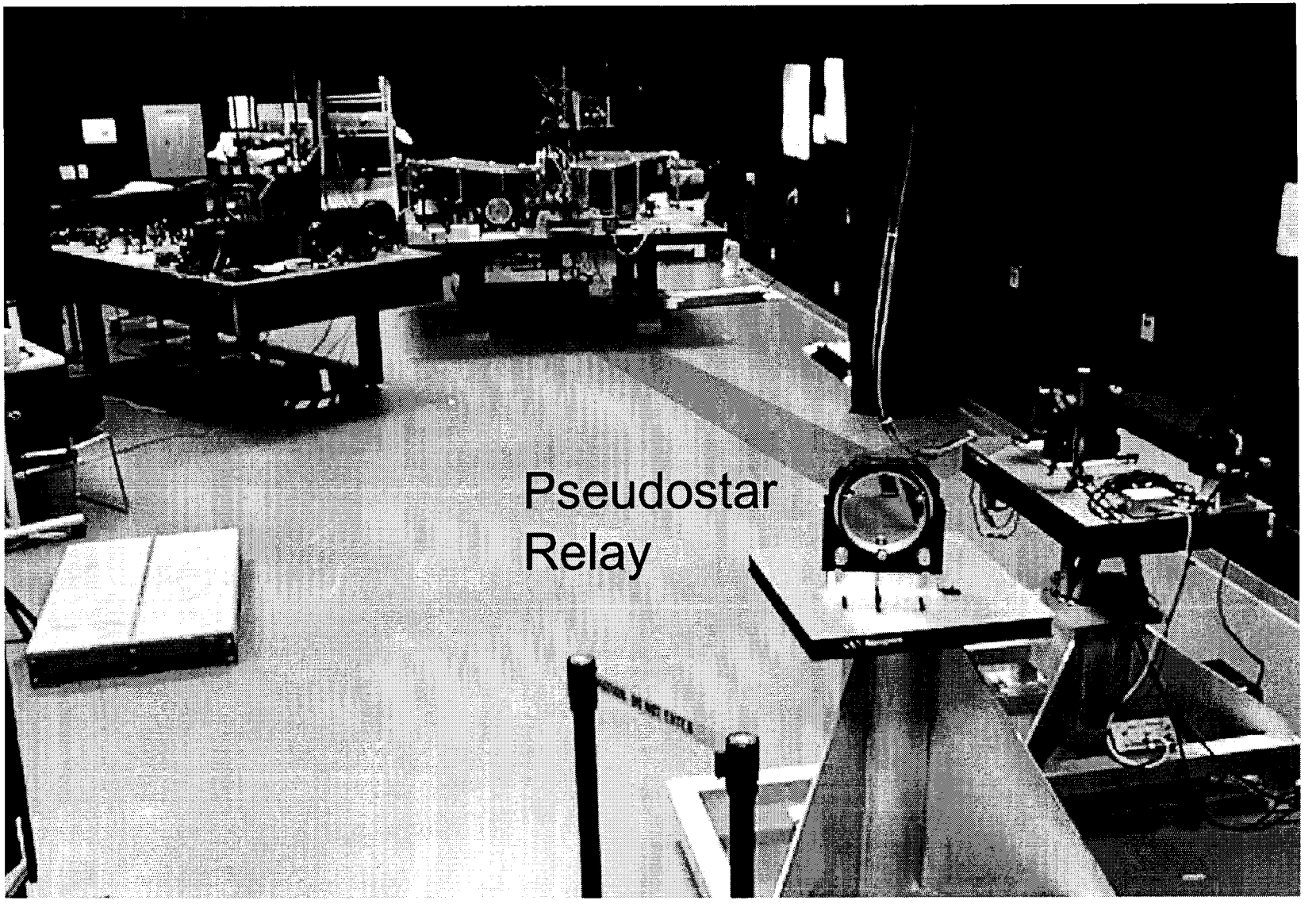
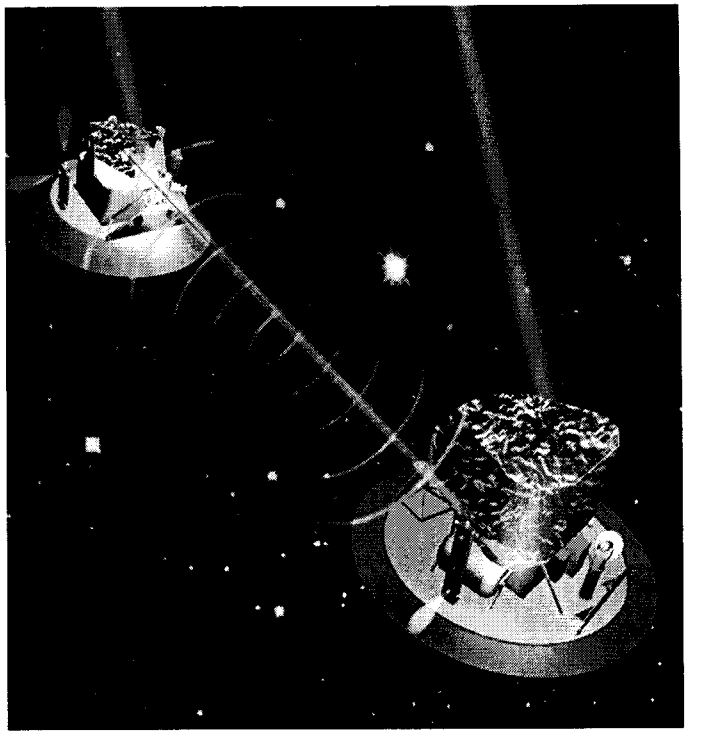
Formation Interferometer Testbed

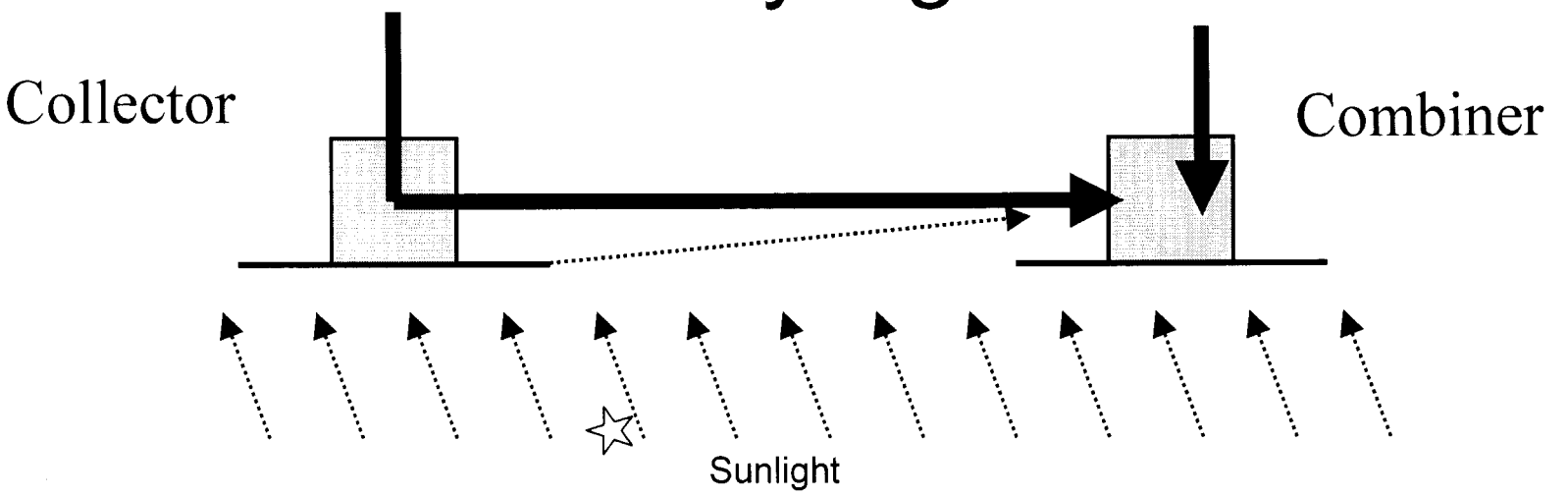


System Complexities Addressed



- Challenges
  - Sufficient closed loop bandwidth
  - Sufficient inter s/c bandwidth
  - Ability to align on orbit
- Couplings
  - AFF/sunshade multipath
  - Optical pointing acquisition
  - Formation trimming
  - Vibration environment
  - Number of states of a formation flyer
  - Delay rate and camera rate
  - Stray light

Stray Light



- One way scatter: 4 amin off-axis at 600m
- Mitigation:
  - Knife-edge (100 um radius) on collector sunshield
  - Modest surface quality on first two combiner mirrors to limit scattering on-axis
  - Arcmin field stops at combiner

Summary

- StarLight formation-flying interferometer design has been thoroughly developed
- Required technology has been developed – described in following presentations in today's sessions
- Is there a future for StarLight flight mission?
  - Technology infusion to TPF
  - Possible TPF technology precursor
  - Possibility of other collaborations, for technology demonstration or science